Chapter 5

Technology for Capacity Improvement

There are many technological initiatives underway which promise to improve the capacity of an airport, its surrounding terminal airspace, and the en route airspace. When considered individually, the primary focus of a large number of technologies and projects might be other than capacity enhancement, even so, these technologies are significant steps in the right direction. The impact of each initiative will be enhanced by an integrated approach to capacity improvement that results in effective coordination of the various programs. At a national level, this integration will be accomplished through the activities of the National Simulation Capability described in Section 5.5.1.

Section 5.1 covers technologies applicable to airport surface operations. Section 5.2 discusses programs that apply to the adjacent terminal airspace and directly support the approach procedure improvements discussed in Chapter 3. Section 5.3 discusses technologies applicable to the en route airspace, including oceanic airspace. Section 5.4 addresses capabilities that will support traffic flow managers, both national and local, in maintaining a planned, systematic flow of air traffic. Section 5.5 covers technologies and programs that support planning and integration of the above programs, as well as technologies that will make changes and improvements to the National Airspace System (NAS) easier and more efficient to implement.

The summaries included in this chapter are meant to be general descriptions of technologies and projects, currently underway or under development, which promise to increase system capacity. For a more detailed description of these and other technologies and projects, refer to Appendix H. Many of those projects are also listed in the FAA's R,E&D Plan.

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5.1 Airport Surface Capacity Technology

Taxiway interference, separation at intersections, departure sequencing, and the like, all contribute to surface-related flight delays. The Airport Surface Traffic Automation System (ASTA) will provide automation designed to make ground operations safer and more efficient.

5.1.1 Airport Surface Traffic Automation Program

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The purpose of the ASTA program is to increase aviation safety by reducing runway incursions and surface collisions in the airport movement area and to provide controllers with automated aids to reduce delays and improve the efficiency of surface movement.

The ASTA program comprises five elements: a runway status light system, a surveillance data link, aural and visual warnings, data tags, and a traffic planner. The program will develop an enhanced surface safety system using the Airport Surface Detection Equipment (ASDE-3) primary ground sensor radar, Automated Radar Terminal System (ARTS), Differential (corrected) Global Positioning System (DGPS), Airport Movement Area Safety System (AMASS), and other technologies. ASTA will provide controllers with automatically generated alerts and cautions as well as data tags to identify all aircraft and special vehicles on the airport movement area in all-weather conditions. ASTA will also include a traffic planner that will improve the routing of aircraft on the taxiways and reduce taxi delay times. Future enhancements will include the Cockpit Display of Traffic Information (CDTI) for traffic on the surface. This is expected to be integrated with a CDTI capability for airborne traffic. The ASTA program examines the roles and responsibilities of controllers, pilots, and ground vehicle operators when operating on the airport.

The AMASS is an automation enhancement to the ASDE-3 primary ground sensor radar that provides an initial safety capability on runways and connecting taxiways. After determining that a group of ASDE-3 radar returns make up a target, the AMASS then analyzes that target's position and motions with respect to other targets and the defined airport operational configuration to determine if there are any conflicts among targets or with defined operations. If there are conflicts, a verbal and graphic alert is given to the controllers in the tower cab. The AMASS also has an interface with the Automated Radar Terminal System (ARTS) in order to include airborne aircraft on final approach in the check for conflicting target operations on the airport surface. All airports slated to receive ASDE-3/AMASS equipment will also receive ASTA.

The ASTA program will share information with the Terminal Air Traffic Control Automation (TATCA) program to create an interrelated runway incursion prevention and surface traffic management system. When completed, the ASTA program will provide an all-weather, automated capability that allows for safer, higher capacity airport operations.

5.2 Terminal Airspace Capacity Technology

There are a number of programs that will improve the capacity of an airport's surrounding terminal airspace. The Precision Runway Monitor was discussed in Chapter 3 in connection with procedures for improved landing capabilities at airports with multiple runways. The Differential Global Positioning System (DGPS) and the Microwave Landing System (MLS) will make precision approach procedures available at more runways at more airports by significantly reducing the siting and frequency congestion problems associated with ILS.

The Center-TRACON Automation System will complement the above systems by aiding the controller in merging traffic as it flows into the terminal area. It will also support enhanced air traffic throughput and avoid undesirable bunching and gaps in the traffic flow on the final approach path. This system and the Converging Runway Display Aid have been combined into the Terminal ATC Automation Program. Finally, the Traffic Alert and Collision Avoidance System has the potential to expand beyond its current role of providing airborne collision avoidance as an independent system. It has the potential to reduce aircraft spacing in a variety of situations, leading to increased capacity.

5.2.1 Terminal ATC Automation (TATCA)

The purpose of the Terminal ATC Automation Program (TATCA) is to develop automation aids to assist air traffic controllers and supervisors in enhancing the terminal area air traffic management process and to facilitate the early implementation of these aids at busy airports. The TATCA program consists of two projects: the Converging Runway Display Aid (CRDA)/ Controller Automated Spacing Aid (CASA) and the Center-TRACON Automation System (CTAS). Longer-term TATCA activities include the integration of terminal automation techniques with other air traffic control and cockpit automation capabilities.

5.2.1.1 Converging Runway Display Aid/ Controller Automated Spacing Aid

The CRDA displays an aircraft at its actual location and simultaneously displays its image at another location on the controller's scope to assist the controller in assessing the relative positions of aircraft that are on different approach paths. The CRDA function is now implemented in version A3.05 of the ARTS IIIA system.

Actual operations have shown that CRDA is effective in increasing capacity by allowing multiple runways to be used simultaneously under IFR.

The Controller Automated Spacing Aid (CASA) project is developing new applications to support the synchronizing of aircraft in separate streams of traffic.

Actual operations have shown that CRDA is effective in increasing capacity by allowing multiple runways to be used simultaneously under IFR. At St. Louis, the FAA has conducted a demonstration of this tool to measure its effect on dependent precision converging approaches in near Category I minimums. Results from field testing at St. Louis have shown an increase in arrival rates from 36 arrivals per hour to 48 arrivals per hour, an increase of 33 percent. National standards for CRDA were published in November 1992. Other airports such as Philadelphia International, Boston Logan International, Washington Dulles International, and Greater Cincinnati International are using or developing a use for CRDA.

While the original purpose of CRDA was to support specific procedures for converging approaches, other procedures can be supported by CRDA automation or a variant of that technology. The Controller Automated Spacing Aid (CASA) project is developing these other applications. In general, these new applications support the synchronizing of aircraft in separate streams of traffic. The applications range from support for more effective merging of aircraft in the terminal area prior to the approach phase to support for taking full advantage of available runway geometry with asymmetrical staggered approaches.

5.2.1.2 Center-TRACON Automation System

Approaches to major terminal areas represent one of the most complex and high-density environments for air traffic control. Arrivals approach from as many as eight directions, with jet arrivals descending from high altitudes while other traffic enters from low altitudes. It is difficult for controllers to foresee how traffic from one approach path will ultimately interact with traffic from other approach paths. This results in traffic arriving either in bunches, which leads to higher controller workload and increased fuel burn to maintain separation, or with significant gaps, which in turn reduces airport capacity. Speed and space restrictions in the terminal area add to the difficulty of maintaining an orderly flow to the runway. Visibility and wind shifts, variations in aircraft mix, wake vortex considerations, missed approaches, runway changes or closings, all add to the difficulty of controlling traffic efficiently and safely in the terminal airspace.

CTAS is designed to improve system performance (e.g., efficiency, capacity, controller workload), while maintaining at least the same level of safety present in today's system, by helping the controller smooth out and coordinate traffic flow efficiently. The earliest CTAS product is the Traffic Management Advisor (TMA), with one TMA specifically designed for the Center environment (CTMA) and one for the TRACON (TTMA). The TMA determines the optimum sequence and schedule for arrival traffic, and coordination between air traffic control facilities such as a Center and a TRACON is managed via the TMAs for the respective facility. Other CTAS products are the Final Approach Spacing Tool (FAST) for the TRACON and a Descent Advisor (DA) for the ARTCC. FAST aids TRACON controllers in merging arrival traffic into an efficient flow to the final approach path and also supports controllers in efficiently merging missed approach and pop-up traffic into the final approach stream. DA assists Center controllers in meeting arrival times efficiently while maintaining separation.

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A CTAS functionality under concept exploration is Expedite Departure Path (EDP). EDP is intended to accurately model aircraft ascent up to cruise altitude. Ultimately this knowledge can be used in the terminal and en route environments to interleave departing aircraft into the existing flow of en route aircraft.

Each of the major components of CTAS, TMA (both CTMA and TTMA), DA, and FAST will be assessed in an operational environment at one or more sites prior to development and limited national deployment. Operational assessment of TMA began in 1993 and will continue in 1994. Operational assessments of FAST and DA will begin in 1994 and continue through 1995. Longer-term CTAS activities focus on integration of terminal automation with other ATC automation and cockpit automation activities.

5.2.2 Precision Runway Monitor (PRM)

The PRM consists of an improved antenna system that provides high azimuth and range accuracy and higher update rates, a processing system that monitors all approaches and generates controller alerts, and a high resolution display system.

Significant capacity gains can be achieved at airports with closely-spaced parallel runways if the allowable runway spacing for conducting independent parallel instrument approaches can be reduced. (The benefits associated with reduced spacing are discussed in Section 3.1.) Current criteria allow independent approaches to parallel runways separated by 4,300 feet or more. This standard was established based in part on the surveillance update rate and accuracy of the airport surveillance radars (ASRs) and the terminal Automated Radar Terminal System (ARTS) capabilities. Analysis and demonstrations have indicated that the separation between parallel runways could be reduced if the surveillance update rate and the radar display accuracy were improved, and special software was developed to provide the monitor controller with alerts. Conventional airport surveillance radars update the target position every 4.8 seconds.

The FAA fielded engineering models of the PRM system to investigate the reduction in separation associated with these improvements. The PRM consists of an improved antenna system that provides high azimuth and range accuracy and higher update rates than the current terminal ASR, a processing system that monitors all approaches and generates controller alerts when an aircraft appears to be entering the "no transgression zone" (NTZ) between the runways, and a high resolution display system. The E-SCAN PRM uses an electronically scanned antenna that is capable of updating aircraft positions every half a second.

Procedures to allow independent parallel operations for runways as close as 3,400 feet apart were published in 1991. Further research and development, including ATC simulations at the FAA Technical Center, are planned to determine the requirements for conducting independent parallel approaches to runways as close as 3,000 feet apart.

A contract was let in the spring of 1992 for procurement of five electronically scanned (E-SCAN) PRM antenna systems, with delivery planned for 1994.

5.2.3 Precision Approach and Landing Systems

The Instrument Landing System (ILS) has provided dependable precision approach service for many years. However, inherent characteristics of the ILS cause difficulties in congested terminal areas. Of particular concern from an air traffic perspective is the long straight-in flight path required by ILS. Although not a major concern for isolated airports without obstruction problems, for closely spaced airports, ILS finals often create conflicts because flight paths may cross in ways that preclude separation by altitude. In these configurations, the airports become interdependent (i.e., preferred operations cannot be conducted simultaneously at the affected airports), causing delays and constraining capacity. In areas such as New York, the curved approach capability provided by either the Microwave Landing System (MLS) or the Differential Global Positioning System (DGPS) will provide a solution to the interdependency of proximate airports.

MLS was designed to solve ILS difficulties in the terminal area. In the meantime, various implementations of DGPS have shown promise as precision approach and landing systems in initial research and development flight tests. A DGPS system would be based on the Department of Defense's (DOD's) Global Positioning System (GPS) augmented with ground reference stations and possible additional satellites to provide the accuracy, integrity, continuity, and availability of service required of a precision landing system. It is expected that DGPS will provide many of the same capabilities as MLS at a lower cost. To help determine the future precision approach and landing system for the National Airspace System (NAS), the FAA has initiated the National Airspace System Precision Approach and Landing System (NASPALS) study.

In general, the remote area navigation (RNAV) capability with wide-area coverage provided by MLS and DGPS will result in more flexibility in the terminal airspace. RNAV will permit the design of instrument approach procedures that more closely approximate traffic patterns used during VMC. Typically these result in shorter flight paths, segregation of aircraft by type, reduction of arrival and departure gaps, and avoidance of noise-sensitive areas.

MLS and DGPS will also enable the FAA to provide precision approach capability for runways at which an ILS could not be used due to ILS localizer frequency-band congestion or FM radio transmitter interference. For example, it is already difficult to add ILS facilities in congested areas such as Chicago and New York.

It may be possible to achieve lower minimums with MLS and DGPS than can be achieved with ILS at some sites. Moreover, both MLS and DGPS will relieve surface congestion resulting from restrictions caused by ILS critical area sensitivity to reflecting surfaces such as taxiing and departing aircraft.

Use of MLS or DGPS back azimuth for missed approach guidance may help support development of approach procedures for converging runways and triple runway configurations. Use of MLS or DGPS back azimuth for departure guidance will help ease airspace limitations and restrictions on aircraft operations due to noise abatement requirements.

Both MLS and DGPS will provide for more flexible ground siting of equipment to compensate for terrain irregularities that do not permit a centerline siting. Additionally, MLS and DGPS do not require as extensive a site preparation as the ILS glide slope, since they do not form guidance signals through ground reflection. One form of DGPS, known as the Wide Area Augmentation System (WAAS), could potentially provide a precision approach service at all runway ends. This technology would require equipment at a relatively few sites to establish the system. No site preparations would be required at individual airports.

The NASPALS study will be completed in late 1994. The recommendations provided by the study will be used in formulating the U.S. position on precision approach and landing systems for the International Civil Aviation Organization (ICAO) meeting scheduled for early 1995. At this meeting, ICAO members will reexamine the currently planned transition from ILS to MLS.

5.2.4 Traffic Alert and Collision Avoidance System (TCAS) Applications

TCAS is an airborne system that operates independently of ground-based ATC to provide the pilot with advisories concerning nearby transponder-equipped aircraft. The TCAS II system provides relative position information and, when necessary, advisories for vertical maneuvers to avoid collisions. This system is now fully implemented on transport category aircraft.

TCAS is an airborne system that operates independently of ground-based ATC to provide the pilot with advisories concerning nearby transponder-equipped aircraft. The TCAS II system, mandated for use in transport category aircraft, provides relative position information and, when necessary, advisories for vertical maneuvers to avoid collisions. This system is now fully implemented on transport category aircraft. A new version of the collision avoidance logic, which was developed to address operational issues that arose during its phased implementation, has been mandated for installation by December 31, 1994. Because of the situational information provided by TCAS and its widespread equipage, it has been identified as having the potential to increase ATC capacity and efficiency and reduce controller workload.

A program began in FY94 to investigate the use of TCAS to enable in-trail climb maneuvers through the altitude of another TCAS-equipped aircraft in the oceanic airspace. Air carrier service trials of this procedure are slated to begin in late summer 1994. Later, it is anticipated that other programs will investigate the use of TCAS to extend visual approach procedures to lower minimums, support reduced spacing on final approach, reduce the stagger requirement for dependent converging approaches using the CRDA, allow departures at reduced spacing, and monitor separation between aircraft on independent approaches. Should these applications prove successful, additional development will be pursued in the areas of TCAS-based parallel approach monitoring, TCAS-based self-spacing, and other more advanced applications.

5.2.5 Wake Vortex Program

A better understanding of wake-vortex strength, duration, and movement could result in the reduction of aircraft separation criteria. Revised wake-vortex separation criteria may increase airport capacity by 12 to 15 percent in instrument meteorological conditions (IMC), thereby enhancing airspace use and decreasing delays.

Several vortex detection and measurement systems will be deployed at selected airports to monitor wake-vortex strength, transport characteristics, and decay. Wake vortex data obtained from these airports will be combined with data from tower fly-by tests already completed to provide a basis for reviewing existing separation standards and recommending modifications to those standards.

Plans include cockpit simulations to determine if separation standards for heavy aircraft operating behind heavy aircraft can be reduced from four miles in trail to three miles. This will be followed by examining the separation for large-behind-large and issues relating to closely spaced runways, departure delays, and departure sequencing which would interconnect with terminal automation.

5.2.6 Terminal Area Surveillance System

Although air traffic incidents may occur during any phase of flight, the largest percentage occur during takeoff and landing. Currently, there are many airports without surveillance radars, and the airport surveillance radar being procured by the FAA, the Airport Surface Detection Equipment-3 (ASDE-3), will not be available at all airports due to cost considerations. It is important, therefore, to develop affordable sensors to provide a reliable surveillance source for terminal operations and to support automation development and airport capacity initiatives.

Requirements for a new terminal area surveillance radar have been identified and include modular, cost-effective primary and secondary radar systems with application for flexible, high capacity data links, improved surveillance accuracy, improved runway monitoring, improved wind shear detection and dissemination, and improved wake vortex tracking. Efforts will focus on adapting commercial technology in order to develop a radar that meets the validated requirements in a cost-effective manner.

5.3 En Route Airspace Capacity Technology

En route airspace congestion is being identified increasingly as a factor in restricting the flow of traffic at certain airports. Initiatives designed to reduce delays, match traffic flow to demand, and increase users' freedom to fly user-preferred routes are underway.

En route airspace congestion is being identified increasingly as a factor in restricting the flow of traffic at certain airports. One cause of en route airspace congestion is that ATC system users want to travel directly from one airport to another at the best altitude for their aircraft, and hundreds of aircraft have similar performance characteristics. Therefore, some portions of airspace are in very high demand, while others are used very little. This non-uniform demand for airspace translates into the need to devise equitable en route airspace management strategies for distributing the traffic when demand exceeds capacity. Initiatives designed to reduce delays, match traffic flow to demand, and increase users' freedom to fly user-preferred routes are underway.

Automated En Route Air Traffic Control (AERA) is a long-term evolutionary program that will increasingly allow aircraft to fly their preferred routes safely with a minimum of air traffic control intervention. The Advanced Traffic Management System (ATMS) will allow air traffic managers to identify in advance when en route or terminal weather or other factors require intervention to expedite and balance the flow of traffic.

The need for increased efficiency in oceanic airspace is also being addressed. Initiatives that improve the control of this airspace, particularly the more accurate and frequent position reporting resulting from Automatic Dependent Surveillance (ADS) using satellite technology, will make it possible to effect significant reductions in oceanic en route spacing.

Other means of improving en route airspace capacity include reducing the vertical separation requirements at altitudes above FL290 to allow more turbojet aircraft to operate along a given route near their preferred altitudes and reducing the minimum in-trail spacing to increase the flow rate on airways.

5.3.1 Automated En Route Air Traffic Control (AERA)

AERA is a collection of automation capabilities that will support ATC personnel in the detection and resolution of problems along an aircraft's flight path in coordination with traffic flow management. AERA will help increase airspace capacity by improving the ATC system's ability to manage more densely populated airspace. AERA will also improve the ability of the ATC system to accommodate user preferences. When the most desirable routes are unavailable because of congestion or weather conditions, AERA will assist the controller in finding the open route closest to the preferred one.

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Laboratory facilities for the AERA program were established in 1987. This laboratory has been used for prototyping and analyzing systems and concepts to develop operational and specification requirements, as well as supporting technical documentation. Initial algorithmic and performance specifications were completed in 1991. These specifications were updated in 1992 to reflect the transition strategy adopted to implement AERA capabilities. This strategy will minimize disruption of on-going operations and encourage effective assimilation of AERA capabilities by the controller work force.

In 1993, AERA was integrated into the En Route Automation Strategic Plan, which describes how en route automation programs will be incorporated into the National Airspace System over the next 7 to 10 years. Detailed implementation plans are being prepared to bring an initial AERA operational test capability to the field in late 1995 and to implement initial controller use of the AERA capabilities in late 1997. Full AERA capabilities are planned for initial use in the year 2000.

AERA concepts are being introduced in project planning and development for oceanic system automation, traffic flow management, and integration of en route and terminal ATC. In more advanced AERA applications, the integration of ground-based ATC and cockpit automation will be investigated to fully exploit the potential for computer-aided interactive flight planning between controller and pilot.

5.3.2 Automatic Dependent Surveillance (ADS) and Oceanic ATC

ADS will be a part of an Oceanic ATC System to support transoceanic flights over millions of square miles of Pacific and Atlantic airspace. This Oceanic ATC system will provide an automation infrastructure including oceanic flight data processing, a computer-generated situation display, and a strategic conflict probe for alerting controllers to potential conflicts hours before they would occur.

In the ADS System, the information generated by an aircraft's onboard navigation system is automatically relayed from the aircraft, via a satellite data link, to air traffic control facilities. The automatic position reports will be displayed to the air traffic controller in nearly real time. This concept will revolutionize ATC in the oceanic areas that are beyond the range of radar coverage. Currently oceanic ATC is largely manual and procedural and operates with very little, and often delayed, information. It depends upon hourly reports transmitted via High Frequency (HF) voice radio, which is subject to interference. Because of the uncertainty and infrequency of the position reports, large separations are maintained to assure safety. These large separations effectively restrict available airspace, and cause aircraft to operate on less than optimal routes.

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The new Oceanic ATC System will provide benefits to airspace users in efficiency and capacity. The improved position reporting will allow better use of the existing separation standards. Air traffic management will be able to begin the process of reducing those standards, thereby increasing the manageable number of aircraft per route. Using the strategic conflict probe, controllers will be able to evaluate traffic situations hours into the future. Ultimately, controllers will be able to grant more fuel-efficient flexible routes, which will have a significant impact on fuel costs and delays. The final decision to reduce separation standards in oceanic airspace is a joint decision shared by Air Traffic and Flight Standards. The Technical Programs Division (AFS-400) and the Procedures Division (ATP-100) are working together to develop the criteria and programs leading to the reduction of separation standards based on the introduction of Oceanic Datalink (ODS), GPS, and ADS.

5.3.3. Communications and Satellite Navigation

New technology enhancements in communications, navigation, and surveillance provide the basis for dramatic improvements in aviation system performance, including improved safety, reduced delay, increased capacity, and greater efficiency. These three functional areas represent key elements of the air traffic management infrastructure.

5.3.3.1 Aeronautical Data Link Communications

Data link services should relieve congestion on voice communications channels and provide controllers with an ability to handle more traffic during peak periods while providing pilots with unambiguous information and clearances. This benefit has been demonstrated by the delivery of pre-departure clearances via data link.

Data link applications are being developed based on inputs from the air traffic and aviation user communities. These applications include weather products, en route, terminal, and tower ATC communications, and other aeronautical services. The Aeronautical Telecommunications Network (ATN) allows use of many data link sub-networks (e.g., satellite, Mode S, VHF, etc.) in a way that is transparent to the users.

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Domestic standards are being developed with RTCA, and the international standards, with ICAO. The en route, terminal, and tower ATC services are being developed and evaluated by a team of air traffic controllers. The operational aspects and benefits of data link applications will be verified using contractor and FAA Technical Center test beds. Pilot inputs will be gathered by connecting cockpit simulators and live aircraft to the test beds during evaluations.

5.3.3.2 Satellite Navigation

Efforts are underway to augment the Department of Defense's Global Positioning System (GPS) to support civil aviation navigation requirements. Procedures and standards are being developed for oceanic and domestic en route, terminal, non-precision approach, precision approach, and airport surface navigation. Satellite ranging signals currently provide three-dimensional position, time, and velocity information that

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can be used as a supplemental means of navigation for civil users down to non-precision approach. This technology, supplemented to improve system accuracy, availability, and integrity, will eventually provide aircraft the ability to fly direct paths instead of being confined to specific routes, thus providing for more efficient use of airspace. GPS will also allow for increased capacity through reduced separation minimums and provide an accurate position reporting system without separate surveillance systems.

With the declaration of GPS initial operational capability (IOC) in December 1993, the DOD agreed to sustain levels of signal availability and accuracy such that basic federal radio navigation requirements are met. Furthermore, the Joint DOD/Department of Transportation (DOT) Task Force Report, released in December 1993, gave the FAA authority to implement a wide-area integrity and availability enhancement to support expanded civil navigation operations. With demonstrated improvements in position accuracy, GPS may prove capable of providing an all-weather landing service by the turn of the century.

The satellite navigation program is working with the communications, navigation, surveillance (CNS)/satellite system manager and systems engineering to transition to the future National Airspace System Precision Approach and Landing System (NASPALS). Candidate system architectures being developed and evaluated are hybrids of space and terrestrial-based systems, including GPS. The goal of the program is to compare the performance, cost, operational capability, and risk of each architecture and select the best candidate as the U.S. position for international standardization.

Weather is the single most important factor in delays and a major factor in aircraft accidents and incidents. Improved weather information can not only increase system capacity, but also enhance flight safety, improve flight efficiency, reduce ATC and pilot workload, improve flight planning, and result in fuel and cost savings.

5.3.4 Aviation Weather

Weather is the single most important factor in delays and a major factor in aircraft accidents and incidents. Improved weather forecasts offer the potential for increasing system capacity more cost effectively than many other alternatives. Improved weather information can not only increase system capacity, but also enhance flight safety, improve flight efficiency, reduce ATC and pilot workload, improve flight planning, and result in fuel and cost savings.

Efforts are underway to enhance our understanding and ability to predict a range of aviation weather phenomena: icing, en route and transition turbulence; ceiling and visibility; thunderstorms and microbursts; en route and terminal wind; and oceanic weather of all kinds. Models and algorithms are being developed for understanding weather and generating short-term forecasts.

To help in the understanding of weather, airborne meteorological sensors are being developed to measure humidity and turbulence. These sensors will be carried aboard aircraft to provide near-real and real-time three-dimensional weather data that is currently not available.

Wind shear is a major cause of weather-related fatalities in the air carrier community. Research is underway to develop advanced wind shear warning systems and flight crew decision aids. The technology will be transferred to manufacturers and operators to accelerate the development of these systems. Once developed, flight tests will be conducted to evaluate onboard airborne wind shear sensor performance by flying the test aircraft into wind shear. Also, a wind shear training program will be developed for air taxis, commuter operators, and general aviation.

5.4 Traffic Flow Management

The development of improved capabilities to support national and local traffic flow managers has received increasing attention in recent years, and a number of efforts are underway to aid in fielding effective and well designed enhancements to the Traffic Flow Management (TFM) System. Two of the most prominent such efforts are the Advanced Traffic Flow Management System (ATMS) and the Operational Traffic Flow Planning (OTFP) Program. Both of these efforts will focus on formulating and developing improvements for the TFM system in consultation with aviation system users, including both the automation infrastructure and the associated air traffic procedures necessary to implement the operational capability.

5.4.1 Advanced Traffic Management System (ATMS)

The purpose of the ATMS effort is to research automation tools to minimize the effects of NAS overload on user preferences without compromising safety. This is accomplished by:

- Monitoring the demand on and capacity of ATC resources.
- Developing alternative strategies to balance demand and capacity to prevent critical entities from being overloaded.
- Coordinating and implementing strategies to assure maximum use of critical resources when a demand/capacity imbalance is predicted or detected.

The Aircraft Situation Display (ASD) was the first capability developed by ATMS.

The ASD has helped increase system capacity in several ways. It allows traffic management specialists to observe approaching traffic across ARTCC boundaries. This has allowed the reduction or elimination of many fixed miles-in-trail restrictions. It assists traffic management specialists in planning arrival flows for airports that are close to ARTCC boundaries. It allows traffic management specialists to detect and effect solutions to certain congestion problems.

Automation tools shown to be beneficial through the ATMS research and development program will be implemented and fielded for operational use in the Enhanced Traffic Management System (ETMS).

The Aircraft Situation Display (ASD) was the first capability developed by ATMS. The ASD generates a graphic display that shows current traffic and flight plans for the entire NAS. The ASD is currently deployed at the Air Traffic Control System Command Center (ATCSCC) and all ARTCCs and at selected TRACONs and Canadian locations. The ASD data has also been provided to commercial air carriers and air taxi operators, and they are using these data to aid in their operations management and planning.

The ASD has helped increase system capacity in several ways. It allows traffic management specialists to observe approaching traffic across ARTCC boundaries. This has allowed the reduction or elimination of many fixed miles-in-trail restrictions (and the resultant delay of aircraft) that were in effect prior to the deployment of ASD. It assists traffic management specialists in planning arrival flows for airports that are close to ARTCC boundaries, resulting in smoother arrival flows and better airport utilization. It allows traffic management specialists to detect and effect solutions to certain congestion problems, such as merging traffic flows, well in advance of problem occurrence and even before the aircraft enter the ARTCC where the congestion problem will occur. Small adjustments to traffic flows made early can avoid large delays associated with last-minute solutions.

The second capability developed by ATMS was the Monitor Alert, which predicts traffic activity several hours in advance. It compares the predicted traffic level to the threshold alert level for air traffic control sectors, fixes, and airports, and highlights predicted problems. It will aid in detecting congestion problems further in advance, enabling solutions to be implemented earlier. The Monitor Alert has recently been implemented at the ATCSCC, all ARTCCs, and several TRACONs.

Four future capabilities that are being developed through ATMS are Automated Demand Resolution, Dynamic Special Use Airspace, Strategy Evaluation, and Automated Execution. Automated Demand Resolution will examine problems predicted by Monitor Alert and suggest several alternative problem resolutions. The suggested resolutions are planned to respond to each problem without creating conflicts or additional problems. Dynamic Special Use Airspace will provide automation to allow consideration of actual and scheduled military operations in the national flow management decision making process. Strategy Evaluation will provide a tool to evaluate alternative flow management strategies. Automated Execution will generate and distribute facility and aircraft-specific directives to implement selected strategies.

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In addition to domestic flow management capabilities, research is being conducted for oceanic flow management capabilities. Track Generation will define a set of tracks for a prescribed region of airspace. Track Advisory will advise oceanic traffic managers of the most efficient tracks available to individual aircraft approaching the track system. Oceanic Traffic Display will assist the oceanic traffic manager in routing aircraft. Further development will concentrate on the integration of domestic and oceanic capabilities.

5.4.2 Operational Traffic Flow Planning (OTFP)

Increasing congestion, delays, and fuel costs require that the FAA take immediate steps to improve airspace use, decrease flight times and controller workload, and increase fuel efficiency. To achieve these objectives the FAA Operational Traffic Flow Planning program will develop near-term, operational traffic planning models and tools. The program will provide software tools to plan daily air traffic flow, predict traffic problems and probable delay locations, assist in joint FAA-user planning and decision-making, and generate routes and corresponding traffic flow strategies which minimize time and fuel for scheduled air traffic. Benefits include improved aviation safety, airspace use, system throughput, and route flexibility.

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Working directly with commercial aviation interests and other FAA facilities, the Air Traffic Control System Command Center (ATCSCC) can predict problem areas before they occur and generate alternative reroutings and flow procedures. Overall system capacity will be increased over that of the present fixed route and rigid preferred route systems, and increased fuel efficiency, shorter travel times, and reduced delays will result. Controller workloads will decrease from users' participation in a planned, systematic flow of traffic.

5.5 System Planning, Integration, and Control Technology

The NSC is a unique capability that will exploit the latest simulation technology. Horizontal integration brings together diverse system components such as terminal automation, en route automation, oceanic air traffic control, aircraft flight management systems, and mixes of aircraft types and performance in a flexible, interchangeable, and dynamic simulation environment.

The following sections describe technologies that support planning to integrate various improvements into the NAS. Both operational improvements and new technologies need to be evaluated so that they can be developed and implemented effectively, ensuring the interoperability of the elements of the NAS. A large number of models and other technologies will support this integration effort. The National Simulation Capability (NSC), for example, will horizontally integrate many of these new technologies in a laboratory environment. The National Airspace System Performance Analysis Capability (NASPAC) will help in the identification of demand/capacity imbalances in the NAS and provide a basis for evaluation of proposed solutions to such imbalances. Computer-graphics tools, such as the Sector Design Analysis Tool and the Terminal Airspace Visualization Tool, will allow airspace designers to quickly and effectively develop alternative airspace sectors and procedures. They will also reduce the time and effort required to implement these alternatives.

5.5.1 National Simulation Capability (NSC)

The NSC aids and supports the RE&D and systems engineering missions of the FAA by horizontally integrating the various RE&D program elements across the National Airspace System (NAS) environment. The capability to integrate emerging ATC subsystems during the conceptual stage of each project allows early validation of requirements, identification of problems, development of solutions to those problems, and demonstration of system capabilities. It also permits early injection of human factors and system user inputs into the concept formulation process. The net result is a reduction of risk in the development of products for the NAS, faster infusion of new technology, earlier acceptance of new NAS concepts by system users, and greater efficiency in performing the RE&D and systems engineering missions. The ASTA, CTAS, TCAS, AERA, ATMS, OTFP, Aeronautical Data Link Communications, Terminal Area Surveillance System, and Aviation Weather programs are all actively involved in horizontal system simulations in the NSC.

The NSC is a unique capability that will exploit the latest simulation technology. Horizontal integration brings together diverse system components such as terminal automation, en route automation, oceanic air traffic control, aircraft flight management systems, and mixes of aircraft types and performance in a flexible, interchangeable, and dynamic simulation environment. It provides an ability to assess the suitability and capability of emerging ATC system components before production investment decisions are made. The NSC permits the evaluation of new operational concepts, human interfaces, and failure modes in a realistic, real-time, interactive ATC environment capable of simulating new or modified systems at forecast traffic levels. Simulation capabilities will be expanded through an interface with various remote research centers that possess nationally unique facilities and expertise.

5.5.2 Analysis Tools

A large and growing repertoire of analytical, simulation, and graphical tools and models are being developed and used to help understand and improve the NAS. Some of the more prominent of these are briefly described in the following sections.

The principal objectives of computer simulation models currently in use and under development are to identify current and future problems in the NAS caused by demand/capacity imbalances and to construct and evaluate potential solutions. All of the models rely on a substantial amount of operational data to produce accurate results. The principal models that are being developed and are in use today are described below.

5.5.2.1 Airport Network Simulation Model (AIRNET)

AIRNET is a PC-based tool that is designed to assess the impact of changes in airport facilities, operations, and demand. It is a planning tool that can assess the effects of those changes on passenger costs, noise contours, airports, airlines, and aircraft. It addresses macro trends and interactions for use in policy planning and economic analysis.

5.5.2.2 Airport and Airspace Simulation Model (SIMMOD)

SIMMOD simulates both airports and airspace in a selected geographic area. It aids in the study of en route air traffic, terminal air traffic, and ground operations. It is capable of calculating capacity and delay impacts of a variety of operating alternatives, including runway configurations, airspace routes, sectorization, and separation standards. It is a planning tool for evaluating operational alternatives involving the coordination of airport configurations with airspace configurations. SIMMOD has been used in airspace design studies around major airports. Improvements to SIMMOD include better output displays, automated data-acquisition capability, and a workstation version of the model.

5.5.2.3 Airfield Delay Simulation Model (ADSIM) and Runway Delay Simulation Model (RDSIM)

The Airfield Delay Simulation Model (ADSIM) calculates travel time, delay, and flow rate data to analyze components of an airport, airport operations, and operations in the adjacent airspace. It traces the movement of individual aircraft through gates, taxiways, and runways. The Runway Delay Simulation Model (RDSIM) is a sub-model of ADSIM. RDSIM limits its scope to the final approach, runway, and runway exit.

5.5.2.4 The Airport Machine

The Airport Machine is a PC-based interactive model with graphics that is used to evaluate proposed changes to airfield and terminal configurations, schedules, and aircraft movement patterns. This model has been licensed for use within the FAA and has been used in studies of a number of major airports. Its primary output is extensive data on delays to aircraft movement.

5.5.2.5 National Airspace System Performance Analysis Capability (NASPAC)

The NASPAC Project provides a long-term analysis capability to assist the FAA in developing, designing, and managing the Nation's airspace on a system-wide level through the application of operations research methods and computer modeling. The focal point of the NASPAC Project is the NASPAC Simulation Modeling System (SMS). The NASPAC SMS is a simulation of the entire NAS used to estimate flight delays by modeling the progress of individual aircraft as they move through the nationwide network of airports, en route sectors, routes, navigation fixes, and flow control restrictions. The model has been used to study the current and projected performance of the NAS and to study system improvements such as new airports, new runways, and airspace changes, as well as projected demand changes such as the creation of new air carrier hubs and the introduction of civil tiltrotor flights in the Northeast Corridor.

5.5.2.6 Sector Design Analysis Tool (SDAT)

The SDAT is an automated tool to be used by airspace designers at the 20 Air Route Traffic Control Centers (ARTCCs) to evaluate proposed changes in the design of airspace. This computer model allows the user to input either the current design or the proposed replacement. It also allows the user to interactively make changes to the design shown graphically on the computer screen.

The model allows the user to play recorded traffic data against either the actual design or the proposed replacement. It also allows the user to modify traffic data interactively in order to evaluate alternative designs under postulated future traffic loading. The model computes measures of workload and conflict potential for the specified sector or group of sectors. This will allow designers to obtain a better balance in workload between sectors, reducing controller workload and increasing airspace capacity. The model will also be useful for facility traffic flow managers, for it will display cumulative traffic flows under either historic or anticipated future traffic loading.

The development of the SDAT has been underway for approximately three years. Procedures for extracting and displaying (in 2D and 3D) all the requisite data from available FAA data files and computing the expected demand for separation assurance actions have been developed. The development of a fully capable controller workload model is underway. SDAT was field tested at two selected sites in FY93, with expanded testing planned for FY94.

A procedure for using the SDAT as an airspace model (assuming that controller workload is the limiting factor) is under development. This will be combined with an on-line Critical Sector Detector for traffic flow management. In addition, a version for terminal area design is under development.

5.5.2.7 Terminal Airspace Visualization Tool (TAVT)

Terminal airspace differs from en route airspace in that it tends to have a more varied mix of aircraft and user types, more complicated air traffic rules and procedures, and wider variation in flight paths. A major redesign of terminal airspace currently requires extensive coordination and the effort of a task force lasting many months or even years. The purpose of the TAVT prototype is to explore the potential for computer-based assistance to such a task force that will support a more rapid evaluation of alternatives.

The TAVT prototype displays a three-dimensional representation of the airspace on a large computer screen to allow the user/operator to view the airspace from any perspective. It also provides an easy-to-use interface that permits the user to modify the airspace according to permissible alternatives. The results of this effort are being evaluated for incorporation into the specifications of a follow-on terminal airspace design tool based on SDAT.

5.5.2.8 Graphical Airspace Design Environment (GRADE)

GRADE is a computer graphics tool for displaying, analyzing, and manipulating airspace design and other aviation related data. Radar data (from both ARTS and SAR) are stripped from their recording media and loaded into GRADE's underlying relational database along with the appropriate airspace geometries, terrain maps, National Airspace System (NAS) data, descriptions of routes, and any other data required in the analysis. GRADE can then be used to test proposed terminal instrument procedures (TERPS), standard terminal arrival routes (STARs) and standard instrument departures (SIDs), airspace design changes, and instrument approach procedures.

GRADE can display radar data in three dimensions, along with the attendant flight plan information, for any given time slice. GRADE also includes a set of algorithms designed to measure interactions between the radar data and any other elements of the database. These measurements can then be displayed as histograms and compared. GRADE provides a high quality, three-dimensional presentation, is relatively easy to use, and can be quickly modified to facilitate the comparison of existing and proposed airspace designs and procedures.

GRADE is currently limited to airspace design applications, but could easily be adapted to other applications, such as noise analysis, interaction with existing airport and airspace computer simulation models, accident/incident investigation (particularly for aircraft without flight data recorders), and training in lessons learned and alternate air traffic control techniques.

5.6 Vertical Flight Program

The Vertical Flight Program will help improve the safety and efficiency of vertical flight operations and increase the capacity of the NAS through research, engineering, and development into air traffic rules and operational procedures, heliport/vertiport design and planning, and aircraft/aircrew certification and training.

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The term vertical flight (VF) includes conventional rotorcraft (helicopters) as well as advanced technology designs for aircraft with the ability to hover and take off and land vertically. The Rotorcraft Master Plan (RMP) envisions advanced VF technologies providing scheduled short-haul passenger and cargo service for up to 10 percent of projected domestic air transportation needs. Recognizing the potential for advanced

VF aircraft to provide passenger service, Public Law 102-581 requested that a Civil Tiltrotor (CTR) Development Advisory Committee be established to evaluate the technical feasibility and economic viability of developing CTR aircraft and infrastructure to support the incorporation of tiltrotor technology into the national transportation system.

Air infrastructure research will focus on the ability to conduct all-weather and IFR operations at heliports and vertiports in terminal airspace without interfering with fixed-wing traffic flow. Much of the initial work relating to emerging technologies will be done through simulation and validated with actual flight test data as the aircraft become available.

Ground infrastructure research will provide RE&D into heliport and vertiport design and planning issues, including the terminal area facilities and ground-based support systems that will be needed to implement safe, all-weather, 24-hour flight operations. Developing obstacle avoidance capabilities is a critical design-related effort. Research will include applying lessons learned from detailed accident and rotorcraft operations analyses. Simulation will be used to collect data, analyze scenarios, and provide training to facilitate safe operations.

Aircraft/aircrew research will develop minimum performance criteria for visual scenes and motion-based simulators; evaluate state-of-the-art flight performance for cockpit design technology; develop improved training techniques employing expert decision making, and develop crew and aircraft performance standards for display and control integration requirements. Research will also be conducted to develop certification standards for both conventional and advanced technology VF aircraft.